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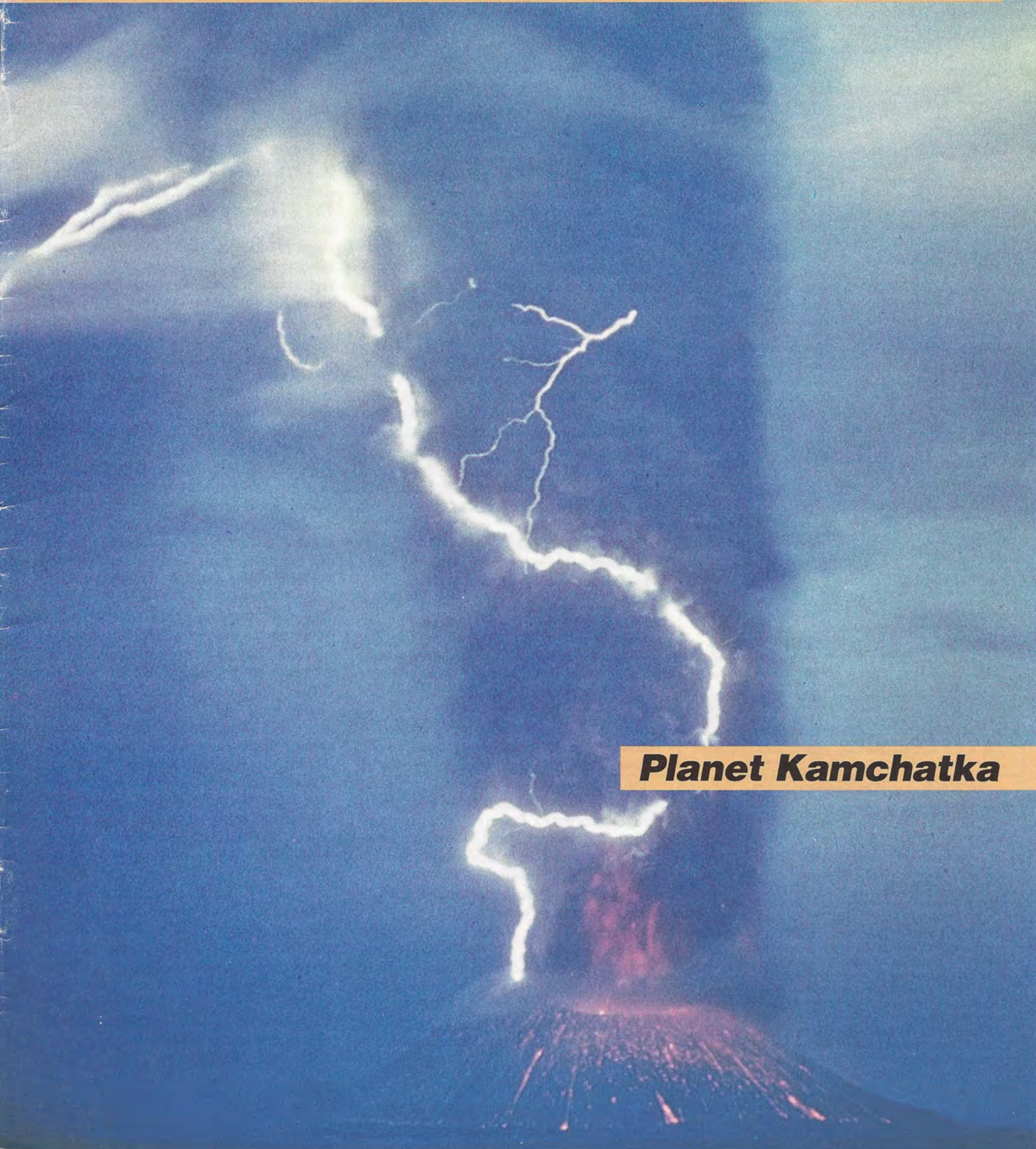

Planet Kamchatka

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COVER: Lightning generated in a plume of ash strikes the volcano Tolbachik, while fresh and still incandescent ash glows on its summit. This volcano on the Kamchatka Peninsula erupted almost continuously from 1971 to 1975, laying down a carpet of ash that has proved to be excellent for testing the mobility of the Mars Rover. In August 1991 Tolbachik was visited by The Planetary Society's Mars Rover team and by a team of US volcanologists. In this issue, we feature reports from both teams. **Photo courtesy of V. Andreev**

FROM THE EDITOR

No one—inside or outside what was the Soviet Union—knows what is going to happen to the now-Russian space program. At The Planetary Society, however, we have extremely close ties to people at several of the institutes involved in the space program. In fact, we hear from our Russian colleagues nearly every day—by phone, fax and electronic mail. They tell us that work on the *Mars '94* and *Mars '96* missions is proceeding according to schedule.

As our members know, we have been deeply involved in these missions for several years, beginning in 1987 with the Mars Balloon and continuing with our tests of the Mars Rover in 1991. The Soviet upheaval threatens this work, but it also provides new opportunities, as we report in this issue.

Page 3—Members' Dialogue—Should the planets be explored by robots or by humans? For years people have debated this question, and the controversy continues among our members.

Page 4—On the Way to Mars—This short report on the 1991 Kamchatka tests of the Mars Rover brings members up to date on the development of this innovative robot designed to traverse the difficult terrains of the Red Planet. The Planetary Society team not only got to observe the rover in action, they were in the Soviet Union during the August coup.

Page 6—Planet Kamchatka—For decades the Kamchatka Peninsula has been as remote as another planet to Western scientists. In the last couple of years a few intrepid Western researchers have managed to visit this volcanic wonderland. This is the story of these expeditions.

Page 11—World Watch—Our Executive Director, Louis D. Friedman, has just returned from a series of meetings in Moscow where he discussed with Russian scientists and engineers the status of their projects. He also reports on the condition of the United States' Space Exploration Initiative.

Page 12—Europa: A World of Superlatives—Being the editor of a magazine like *The Planetary Report* does have its prerogatives: You can choose your personal favorite to be the centerfold. That is what I have done here with this newly reprocessed image of my favorite moon, Europa.

Page 14—News & Reviews—Scientific purists have long complained that the colors of planets seen in press-release images do not reflect the true appearance of these celestial objects. Plus, computers allow image processors to exaggerate other features for effect. Our faithful columnist comes down on the side of purity.

Page 15—Society Notes—The Planetary Society staff is always trying to come up with new and exciting events for our members to attend. In this column, we announce a *Mars Observer* launch tour for our members, their families and friends. We also bring you up to date on other Society activities.

Page 16—Mapping Out a Strategy—While no one has yet established communication with any extraterrestrial being, the scientists and engineers who work in the Search for Extraterrestrial Intelligence (SETI) try to maintain close links with one another. A group of Soviet and American researchers recently met in California, and here we report on their conference.

Page 20—Q & A—Mars has been the recent focus of many of your questions, including this one: Can we steer a balloon on Mars? We also print an alternative answer to a question in our November/December 1991 issue.

Finally, you'll notice that we've changed the format of our sales pages. To give you more information about the items the Society sells, we are no longer simply printing an inventory list for you to choose from. Instead we have selected a few items to describe in more detail. We hope you'll find this more helpful. A complete list of all items offered is available for the asking.

—Charlene M. Anderson

Members' Dialogue

As administrators of a membership organization, The Planetary Society's Directors and staff care about and are influenced by our members' opinions, suggestions and ideas about the future of the space program and of our Society. We encourage members to write us and create a dialogue on topics such as a space station, a lunar outpost, the exploration of Mars and the search for extraterrestrial life.

Send your letters to: Members' Dialogue, The Planetary Society, 65 N. Catalina Avenue, Pasadena, CA 91106.

As a Society member who is strongly in favor of robotic planetary science, it seems to me that the human exploration of Mars misses some important points.

By the time we develop the capability to safely send humans to Mars (by some estimates, the year 2020), the technology of artificial intelligence will have advanced to a point to make it unnecessary to send them. Robotic rovers, smart enough to take care of themselves in the hostile martian environment, will be capable of doing anything a human explorer can do, far more cheaply. These rovers will be able to do things an astronaut or cosmonaut would be incapable of— for example, working around the clock. An automated robot base would be cheaper and less polluting than a human one. Robotic exploration of Mars won't need a space station, a redesigned shuttle, or extensive studies about prolonged human exposure to solar flares.

Exploring Mars with artificially intelligent probes should involve many nations to spread the costs. If we need the public to support this plan in the same way it supports human spaceflight, we could allow the general public to control the activities of one or two of these rovers. That way robotic exploration could be as exciting to the public as human exploration is now.

The Planetary Society has always been a major advocate of robotic planetary science, and I believe its members should think seriously about what can be done with robots before our space agencies send humans to Mars.

—PACE ARKO, *Seattle, Washington*

President Bush has targeted the year 2019 to land humans on Mars. From my standpoint, a 50-year hiatus between the Moon and Mars is a rather poor showing for a technological society that went from Kitty Hawk to the Moon in only 66 years.

I have no intention of downplaying the great scientific leaps made by the robotic probes. In fact, robotic missions are tremendously cheaper and more efficient than human missions. The post-*Apollo* probes have provided a wealth of information. *Voyager*'s revelations of the jovian system are some of the greatest exploratory finds of the century. But in spite of the tremendous scientific leaps brought about by the robotic planetary probes, there is something fundamentally romantic about a group of humans embarked on an odyssey to another planet. It parallels the explorations of Christopher Columbus and James Cook. Robotic probes do not feel the excitement of exploring a new world, nor can they relate their experiences to other people. They do not understand the implication of finding organic compounds, nor do they enjoy the serenity of a sunset.

Practically speaking, human beings can fix things (look at poor *Galileo*), make decisions, interpret information and deal with the unknown. The planetary probes have done an excellent job of mapping phenomena in the solar system, thus compiling a catalogue of things that require further investigation by human beings.

—GREGORY A. VAYDA, *Long Beach, Mississippi*

The caption for the photo of the meteor on page 7 of the November/December 1991 *Planetary Report* is incorrect. I *used* a 1920s camera, I did not *take* the photo in the 1920s. The point was to demonstrate how bright a meteor can be, photographed with a very slow camera lens.

—DENNIS MILON, *Maynard, Massachusetts*

I thoroughly enjoyed the November/December 1991 issue of *The Planetary Report*. In my opinion, it was your best issue yet.

I've always felt that the gap between the erudite, technical realm of space science and the tangible, emotional world that most of us live in is bridged only seldom. After reading your special asteroid issue, I felt the urgency and the reality of the science involved in tracking these rich resources or would-be killers. They have most likely changed the course of life on Earth before and could easily do it again. We'd better be ready.

—T. CHURCHMAN, *Monrovia, California*

NEWS BRIEFS

NASA is studying the possibility of using robotic lunar landers in the late 1990s to gather data needed to establish a permanent lunar outpost, to find sites for astronomical telescopes and to test equipment for converting lunar resources into oxygen, fuel and construction materials.

The radar-guided vehicles, each capable of landing with about 200 kilograms (440 pounds) of hardware on selected areas of lunar terrain, would be built mainly from off-the-shelf hardware, says Stephen Bailey, of the Johnson Space Center's new initiatives office. By developing a common lunar lander, experiment packages geared for different purposes could be targeted to various lunar locales.

—from Leonard David in *Space News*

J. R. Thompson, the number 2 official at NASA, resigned last November. But before he left he recommended sweeping changes—particularly with regard to how money is spent —in the way the space agency works.

NASA has been criticized by Congress for understating true costs when it is presenting a program, or raising the ante when a program is so far along it can't be ended. Thompson said he supports a built-in mechanism to stop programs quickly in such a case, and a new position of chief financial officer to certify that cost projections are in line with commitments.

"This would send a strong message to scientists and engineers that making it better won't do," he said. "Making it cheaper is what we want— with emphasis on making it work."

—from *Spacewatch*

On the Way to Mars:

The 1991 Kamchatka Rover Tests

Not many travelers seek out the most hostile places on Earth and move mountains of bureaucracy to get there. But that is exactly what The Planetary Society's Mars Rover team did last August when they traveled to the Kamchatka Peninsula, a volcanic finger jutting out from the Siberian mainland. Their purpose was to observe field tests of the mobile robot designed to explore a place even more hostile than the frigid lava fields of Kamchatka—the surface of Mars.

The environmental extremes they encountered in Kamchatka were more than matched by the political events that unfolded during their expedition. As team members were making their way to Kamchatka, in the air over the Pacific Ocean, the coup leaders seized power in Moscow.

Obviously, this generated some concern back at Planetary Society headquarters. The team members, Lou Friedman, Tom Heinsheimer, Bud Schurmeier and Roger Bourke, are not the sort to shy away from trouble, and they were encountering a potentially dangerous situation. So we were extremely relieved to receive a fax from Victor Kerzhanovich, our contact at the Space Research Institute in Moscow, which read: "All TPS team members are OK and comfortable. They enjoy good weather and food."

Well, the coup crumbled, the weather turned nasty, but the food remained good for the duration of their trip, as the team reported on their return. They brought back the information they had sought on the Mars Rover, as well as many rolls of film documenting their trip.

These tests were part of a continuing series of experiments conducted by the engineers of the Mobile Vehicle Engineering Institute in St. Petersburg, Russia, to prepare the Mars Rover for its scheduled flight aboard the *Mars '96* spacecraft. The political upheaval in the Soviet Union has made the launch schedule uncertain, but the tests will continue this May. In the desert of California, an international team of Russians, Americans and Europeans will conduct the first full-scale simulation of a Mars prototype rover having autonomous navigation and control.

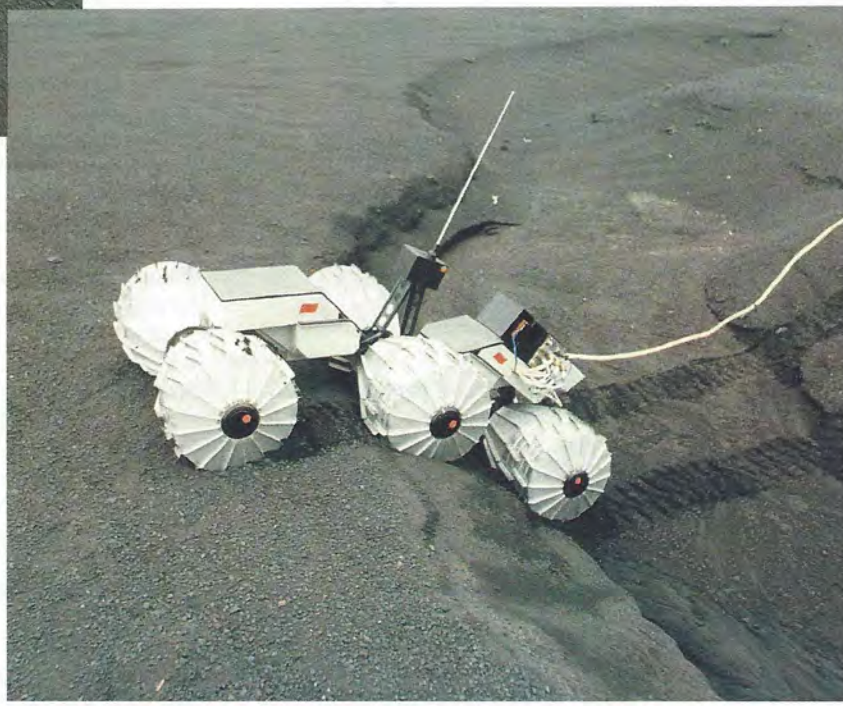
The Planetary Society, through the generosity of its members, is making these desert tests possible. We will keep you apprised of the rover's progress as the team works to prepare it for Mars. —*Charlene M. Anderson*

The jumping-off point for the expedition was Petropavlovsk-Kamchatskii, a city built on a series of hills. To get the lay of the land, they journeyed to a restaurant set on a hilltop that commanded a view of the region. From left to right are Harris M. "Bud" Schurmeier, manager of the Society's Mars Balloon project; Alexander Kermurjian, head of the Mobile Vehicle Engineering Institute and leader of Mars Rover development; Society Executive Director Louis Friedman; aerospace consultant Thomas Heinsheimer; and the chief scientist for the *Mars '96* mission, Viacheslav Linkin of the Soviet Space Research Institute. Roger Bourke of the Jet Propulsion Laboratory took the picture.

The Soviets have established a base camp on the gently rolling hills of Tolbachik volcano. Here the Soviet and American team members were housed together. The camp was a 20-minute ride by four-wheel-drive truck to the test site higher up the slope of the volcano.

To scout potential test sites, the team used an Aeroflot Mi-8 helicopter. Surface transportation over Kamchatka's volcanic landscape is not always possible. When it solidifies, lava can take on particularly jagged forms, with sharp edges that can cut tires as efficiently as broken glass.

A Russian volcanologist uses a sledgehammer to investigate the frozen lava of a potential test site. On Mars, the rover will have to do its own investigating, and it will carry instruments to poke and probe the surface. The full complement of instruments has not yet been chosen, and one purpose of the California tests this spring will be to help determine what the rover will carry on Mars.



ABOVE: The Soviet Mars Rover is a "wheel-walking" machine, with conical wheels attached to a hinged frame. This design allows the segments to move separately or together. For example, to cross a crevasse, the sections can lock into a single, rigid frame. To climb a hill of soft volcanic ash, as during this test, the sections can move forward separately, with two sections anchoring the third as it inches upward.

RIGHT: Mars is crisscrossed with channels apparently carved by flowing water, and a major goal of the Mars Rover mission is to investigate some of these features. Here the prototype easily navigates a small channel cut by rain into the fresh volcanic surface. (This rover model was not equipped with onboard computers, so it was remotely controlled through the white cord extending off to the right.)

It wasn't the bitter cold nor the forbidding terrain that forced our rover team to return to civilization, but a ceaseless rain. Here the combined talents of the Mobile Vehicle Engineering Institute and The Planetary Society are applied to a problem of mobility on Earth.

Photos: Roger Bourke

Planet Kamchatka

by Dave Pieri

I was trained as a planetary geologist, but I don't get to do much planetary geology anymore. More often than not, I find myself hiking or flying around erupting volcanoes. I guess I'm more or less a volcanologist now, and I often wonder about the transition that I made from planetary to terrestrial geology. Yes, there was a funding crunch, and the grass looked greener in terrestrial studies, but there was something deeper, too.

To be honest, I was restless. After all, by the late 1980s all the major planets and satellites, except the Pluto–Charon system, had been seen close up, and, thanks to my famous thesis advisor at Cornell University, I had been in on a lot of the *Viking* and *Voyager* action. For me (Carl, forgive me), the real kick in planetary exploration hadn't been in elegantly wrestling with the details. Rather, the draw had been much more visceral: I just wanted to see what was there. But nearly every major planetary place that we would see for the first time had been seen, and you only get to do that once per technical civilization per solar system. It was time for me to move on.

Secret Kamchatka: A New Place to Explore

On Earth, for geographic and political reasons, there are places that Western geologists know far less about than the planets. One of the most secret has been a remote part of the Soviet Union that lies beyond Siberia, a place called the Kamchatka Peninsula (at upper right on map). It is wedged between the northern Pacific Ocean, the Bering Sea and the Sea of Okhotsk. My interest was piqued: a new place to explore.

In fact, in 1988 Kamchatka might as well have been located on one of the moons of Jupiter or Mars. Many people in America probably still think it's just another brand of vodka. At that time the Soviet military would have gone to great lengths to keep the odd curious United States citizen, or for that matter the odd curious Soviet citizen, well away from the Kamchatka Peninsula in the Soviet Far East. For in Kamchatka were some of the most sensitive of Soviet strategic assets, including a nuclear submarine base and an ICBM impact range.

Besides this, Kamchatka had become an electronic battleground. American RC-135 spy planes were making daily forays up and down all 1,600 kilometers (1,000 miles) of its coast, just outside of Soviet air space, and Soviet long-range radars were keeping a watchful eye on US air space, only 800 kilometers (500 miles) away. After all, it was this electronic hair trigger that had prompted, in part, the tragic Soviet shooting down of an unarmed civilian airliner (KAL 007) after it overflew the southern part of Kamchatka.

Also sobering was the thought that in the Soviet Far East and Siberia were the most far-flung and isolated islands of Stalin's Gulag Archipelago. It really was another world.

My scientific interests in Kamchatka were focused on its volcanoes. Big, active volcanoes, cheek by jowl with the fastest subducting oceanic trench in the world, where 8 to 10 centimeters of oceanic crust per year slide under the continent, producing perhaps the most variegated array of volcanic features on our world. Little had been written about these features in the Western literature, so I wanted to go there. No Americans, however, had legally visited that part of the Soviet Union since 1945, when a platoon of Navy Seabees installed a long-range radio antenna that today still stands outside the city of Petropavlovsk-Kamchatskii.

Getting There: The Direct Approach

Imagine the amused surprise of Soviet and US authorities when, in the spring of 1988 at an international conference, I proposed not only to bring a team of geologists from NASA and the US Geological Survey to Kamchatka, but also to fly over Kamchatka's volcanoes in NASA's Lockheed C-130 Hercules Earth Survey Aircraft. Using the aircraft's thermal infrared and ultraviolet instruments, we would be able to collect data as we did in Hawaii and in Italy over active volcanoes like Mauna Loa and Etna.

While there are a myriad of precise scientific reconnaissance studies that we will eventually carry out with our Soviet colleagues, my initial impulse in attempting this project was pretty simple. As in the case of Mars and the Galilean satellites, I just wanted to see what was there.

The reaction of US military and intelligence authorities was one of disbelief. The general consensus was that Soviet authorities would never let any American investigators into Kamchatka on the ground, let alone permit them to fly a sophisticated US remote sensing aircraft over such a sensitive area.

The reaction of Soviet military authorities was true to form—a blanket refusal. Nevertheless, my friends and

The main city on the Kamchatka Peninsula is Petropavlovsk, home to about 300,000 people whose work includes fishing, farming, light manufacturing and government-sponsored research. Because of its spectacular natural harbor, it is also home to part of the Soviet Pacific nuclear submarine fleet. Less than 25 kilometers (15 miles) from the city's center lie the volcanoes Avachinskii and Koryakskii. Both are still active, and Avachinskii erupted ash in January 1991. For obvious reasons, surveillance of these volcanoes is an important duty of the volcanological institutes in Petropavlovsk.
Photo courtesy of V. Andreev

colleagues from the USSR Academy of Sciences' Institute of Volcanology in Petropavlovsk-Kamchatskii assured me that in Russia, a bureaucratic *nyet* never really means *no*. It is, rather, an indication that the applied pressure has been insufficient.

More political pressure was applied for another year (including some help from The Planetary Society), and on a Saturday morning in September 1990, a team of five American volcanologists found themselves emerging from an Aeroflot Il-62 airliner into the bright subarctic sunshine at Yelezovo Airport, Petropavlovsk-Kamchatskii, USSR.

A crowd of a few dozen colleagues and curious onlookers had gathered to present us with a typical Russian welcome of bear hugs, kisses and bouquets of wildflowers. The Americans had come. For us, in this remote corner of the USSR, beyond Siberia, it was as if we were standing on the soil of another planet. For the Kamchatkans, too, it was as if a spaceship had landed and its strange and curious crew was disembarking. A small, but perhaps scientifically significant, victory for *glasnost*.

Paradise for a Volcanologist

What are the volcanoes like on Planet Kamchatka, USSR? Why are they important enough to buck two of the most formidable bureaucracies in the world to get there? Why are NASA and the USSR Academy of Sciences willing to establish a joint research group to study them?

To begin with, the Kamchatka Peninsula is one of the most volcanically active sites on Earth. In Kamchatka, at any given time, are at least 30 active volcanoes of a variety of descriptions. They are the geologic result of the vigorous subduction of the northwest Pacific plate under the Kamchatka mini-continental block.

In fact, the Pacific Ocean is almost completely outlined by a rim of volcanoes so active that it is called the Ring of Fire. This activity is driven by plate tectonics, when large sections of Earth's crust slide slowly across its surface, rubbing against each other. In some places, one plate slides beneath another in a process called subduction. Where this occurs, volcanic activity is usually not far behind.

The Kamchatka situation is of particular interest because the Emperor Seamount Chain, a string of submerged volcanoes, is being subducted pell-mell into the Kurile–Kamchatka Trench. The Emperor chain is the northwesternmost part of a hot-spot track jogging diagonally across the Pacific basin.

Beneath the Pacific lies a place where molten magma from Earth's interior almost continuously erupts through the crust. As the crustal plate moves across this hot spot, a chain of volcanoes is created, one after another. At the most southeastern part of this track are the Hawaiian Islands. The subduction of this hot-spot track system is unique at this time on Earth, and it is producing an interesting and unique magma chemistry in the volcanoes of Kamchatka.

Perhaps connected with the subduction arrangement is a diversity among Kamchatka's volcanoes that is unusual to say the least. Kliuchevskoi bears a geometric similarity to Mount Fuji in Japan, although it is far less hospitable and much more rugged. It is one of the tallest volcanoes in the world (about 5,000 meters or 16,000 feet), measured from sea level, and has been active continuously, at least in historic times.

The Soviet Academy of Sciences has monitored Kliuchevskoi since right after the Bolshevik Revolution. The Institute of Volcanology in Kamchatka in fact dates from that time, making it one of the world's oldest.

The Kliuchevskoi volcano is part of a larger structure called the Kliuchevskoi Shield, a broad accumulation of lava that includes several other separate and distinct volcanic structures. Bezamyanny is very similar to Mount St. Helens in the US, having undergone an enormous lateral eruption in 1956 that sent volcanic ash and aerosols around the world. Currently Bezamyanny is experiencing a dome-building phase, gently oozing lava that cools, hardens and seals off its throat.

On our second field expedition to Kamchatka, in August 1991, our team from the Jet Propulsion Laboratory and the US Geological Survey was able to observe thermal emissions from this very dangerous and unstable dome (about 250 to 300 meters, or 800 to 1,000 feet, high) using a US thermal infrared imaging system deployed on board a Soviet Mi-8 helicopter flying about 1,000 feet above the feature. An eruption from this volcano could be imminent.

The other large volcano on the Kliuchevskoi Shield is Tolbachik, which last erupted during the early 1970s. The "Great Tolbachik Fissure Eruption" created several large cinder cones, 300 to 400 meters (about 1,000 to 1,300 feet) high, and a variety of both aa (very rough) and pahoehoe (very smooth) Hawaiian-style lava flow fields. Covering the lava are broad deposits of scoria, or volcanic ash, that came from several enormous fire fountains several thousand meters high.

On this black landscape of lava

blocks and scoria, Soviet scientists and engineers have extensively tested their prototypes of the rolling rovers that they one day hope to send to Mars. I first observed the operation of these prototypes (and even drove one!) in September of 1990. In late August of 1991, a group of US engineers sponsored by The Planetary Society also visited Kamchatka, conducting extensive discussions with Soviet workers at the Tolbachik rover site and observing the operation of advanced rover prototypes. The ubiquitous cover of ash and intermittent lava blocks makes the Tolbachik terrain an ideal Mars analogue.

South from the Kliuchevskoi Shield, toward the tip of Kamchatka, are additional active volcanoes with names like Mali Semliachik, Avachinskii, Ksudach and Karymskii—names that at one time were almost unpronounceable to me, but now, after two field seasons in the region, roll off the tongue like the names of old friends. These features are just a few of the active volcanoes that run down the spine of the peninsula. Each is peculiar in its own way and very dangerous.

During our second field season, for instance, a Soviet graduate student was killed when he fell into a collapsed steam and acid vent. Every year or so, one or two people are killed while climbing on Kliuchevskoi volcano itself. The high latitude (53 to 56 degrees north) of this volcanic range gives rise to permanent snowfields and glaciers on their slopes, which occasionally produce large mudslides and avalanches that are dangerous to researchers and climbers. This makes remote sensing techniques even more apropos to their study.

Both Regional and Global Effects

As we US investigators become more familiar with these volcanoes, we are beginning to understand their power and their potential influence on Earth's environment. For instance, over the last 10 years international air traffic along the northwest Pacific corridor has increased significantly, with much traffic originating in Europe and heading south to Japan, Hong Kong and Singapore. Airborne volcanic ash is a significant threat to the well-being of turbine engines, which ingest enormous quantities of air during every instant of their operational life.

The vulnerability of jet aircraft to volcanic ash ingestion was almost tragically demonstrated with the near-

One night during our field trip in 1990, snow fell on Karymskii. Two mornings later we noticed fresh ash darkening the western slope of the cone. The helicopter took us to the summit, 1,442 meters (4,732 feet) above sea level, where we looked down into the still steaming crater. In the background is Karymskii Lake, produced during a series of enormous eruptions thousands of years ago.
Photo: David Pieri

In 1988, the French SPOT satellite imaged the Kliuchevskoi Shield in central Kamchatka. The largest and most symmetrical cone is Kliuchevskoi itself, rising nearly 5 kilometers (16,000 feet) above sea level. To the left lie Bezamyanny, which erupted catastrophically in 1956, and Tolbachik, which erupted from 1971 to 1975. To the right is Shiveluch, which erupted more recently. In the middle of this volcanic assemblage stands Kliuchii City, with a population of tens of thousands, on the banks of the Kamchatka River. The city and the nearby Soviet air base (as seen by its 3-kilometer-long runways) are closed to outsiders. (North is to the right in this image.)
© SPOT Image, 1988; processing courtesy of M. Abrams, JPL

In August 1991, using the workhorse Mi-8 helicopter, we circled the growing dome of Bezamyanny, 2,770 meters (9,100 feet) above sea level. The dome sits in a large crater formed during the massive 1956 eruption. While we were there, hot volcanic debris continually cascaded down the east face of the dome, and steam and sulfur dioxide spewed out copiously. Photo: David Pieri

Today the cones of Tolbachik (seen erupting on this magazine's cover) are quiet, except for some slight steaming as rainwater boils back up through cracks in the structure. This view from our helicopter shows a large solidified lava flow, about 150 meters (about 500 feet) wide, that breached the cone during a later phase of the eruption. Photo: David Pieri

Kliuchevskoi erupts. Soviet researchers are concerned that this volcano could collapse catastrophically, as its neighbor Shiveluch has done and as Mount Etna in Sicily did thousands of years ago. Volcanologists often climb to the summit and flank vents to sample erupting lava, and they face both rock and snow avalanches in the process. Nearly every year, climbers are killed on this volcano. Photo courtesy of A. Khrenov

downing of a KLM Boeing 747. The airliner experienced a four-engine flameout over mountainous terrain in Alaska after it flew through a volcanic ash cloud generated during the eruption of Mount Redoubt. Similar, but fortunately less catastrophic, encounters occurred during the recent eruption of Mount Pinatubo.

Since the main north Pacific oceanic air routes parallel the axis of the Kamchatka Peninsula and are generally downwind, aircraft flying in the region are susceptible to contact with airborne volcanic ash and gases when these volcanoes are erupting. Thus, within the aviation community there is high interest in disseminating current knowledge of the activity of these volcanoes, something that has become possible only with the advent of *glasnost*, and with the admission of Western volcanologists to the region.

The Kamchatka volcanoes are also important in a planetary sense. Since they are near-polar volcanoes, the airborne products of their eruptions are initially confined to Earth's polar circulation system. Because these volcanoes are tall and because, at these latitudes, especially during the winter, the cold temperatures bring stratospheric air to lower altitudes, eruptions from these features can deliver almost directly to the stratosphere large quantities of volcanic dust, water ice crystals, sulfur dioxide, halogen gases and acids, and aerosols. Such agents all generally promote, either directly or indirectly, chemical reactions with ozone.

Since the integrity of Earth's ozone layer is already constantly compromised by man-made chlorofluorocarbons, the impact of an additional burden of large amounts of volcanic gases, aerosols and particulates in this vulnerable polar zone of the atmosphere could be significant. The matter is currently under study by our group at JPL, in collaboration with Soviet colleagues from the Institute of Volcanic Geology and Geochemistry in Petropavlovsk-Kamchatskii.

Looking Ahead

Going to Kamchatka was for me, geographically and culturally, the equivalent of exploring a part of a newly discovered planet. Geologically, it is important that such regions be understood for reasons of basic science, as well as to protect the populations that live nearby, and to understand the global impact that they may have

The volcano Loki erupts on Io, one of the four large moons of Jupiter. The active volcanism of Io was one of the major discoveries of the Voyager *mission.* *Image: JPL/NASA*

Otherworldly Volcanoes

We really should have expected it. In retrospect, it seems almost silly that it took a group of trained geologists over 100 days after *Voyager 1* flew by Io to discover that this moon of Jupiter had active volcanoes. In the imaging data, we had even captured several of them *flagrante delicto.*

Our professional training, as cosmopolitan as we thought it was in 1979, was still steeped in terrestrial-planet chauvinism. And, after all, Jupiter and its moons were the first outer-planet system we had encountered; the Saturn, Uranus and Neptune flybys still lay years in the future. As a group, we *Voyager* scientists were snookered by our tendencies to see what we wanted to see. We had been taught to relate new phenomena to old, even though we were seeing alien worlds with unique environments and histories. The new lesson taught by Io's erupting volcanoes alone was worth the price of admission, and it has stayed with me since those exciting days.

On Earth's closest relatives, Venus and Mars, we see classic volcanic mountains nearly identical to terrestrial cinder cones and shield volcanoes—as well as some forms unique to those worlds. In fact, whenever you have big, solid bodies in the solar system, you will probably have volcanic activity.

A volcano forms because almost all solid bodies either are or were out of equilibrium with respect to energy. Simply put, less dense and hotter interior material tends to move toward the cooler regions near the surface, thereby contributing to eventual equilibrium. When hot magma finally breaks through to the surface, a volcano forms.

This process can take a very, very long time, generally in proportion to the size of the body. Over such a long period, volcanism can make major contributions to planetary oceans and atmospheres, as volatile compounds, such as carbon dioxide and water, are liberated from the hot interior. (Impacting comets may import additional volatiles.) If the planet's or satellite's gravity is strong enough to hold them, these volatiles remain for a long time and modify the surface environment.

In at least one local case, we know that such volcanically derived (and cometary) volatiles, over time, have formed self-replicating chemical complexes that eventually went on to write magazine articles about themselves. In another nearby example, Mars, we know that volatiles existed long enough at the surface to carve enormous watercourses and possibly even oceans. There, however, the low planetary mass allowed the volatiles to escape, and the planet's wet epochs were limited to the distant past.

Other diverse environments have produced types of volcanic activity that strain the silicate-dominated, Earth-biased (actually, Mercury-Venus-Earth-Mars-biased) view of volcanism that we geologists often maintain. On Io, there is good evidence that some of the volcanoes are now spewing out sulfur magmas and sulfur dioxide gas. Part of the reason for this is the strong tidal interaction with the other large satellites and with Jupiter, combined with the chemistry of the jovian system. On Europa, water-based magmas may be the dominant erupting materials, even now. And Callisto may have experienced water-based volcanism in the past.

Saturnian, uranian and neptunian satellites have stranger chemistries, by our terrestrial standards. There we may find eruptions of different phases and combinations of exotic volcanic materials, such as methane and ammonia, that exist only as gases under normal Earth-surface conditions.

Although we've now seen a variety of volcanic features throughout the solar system, our most accessible examples are, of course, here on Earth. Thus, whatever we learn about volcanoes in Kamchatka or Hawaii or Ethiopia benefits us as we learn how to protect us planetary inhabitants and our environment. And the study of the full panoply of volcanic activity in our planetary neighborhood, under differing gravities, chemistries and histories, can only help volcanologists understand more fundamentally how volcanoes evolve and how they modify the planets they occupy, including, and especially, this one. —*DP*

when their volcanoes erupt. Perhaps at least as important, though, is what our newly granted access to what was one of the most secret parts of the USSR says about the current state of relations between Russia and the US, and indeed, the rest of the world.

By the way, negotiations to bring the NASA C-130 to Kamchatka are proceeding apace. Soviet scientists have recently sweetened the deal and have offered the use of a previously unknown (to us) Ilyushin 18-D imaging radar aircraft to fly along with our NASA Hercules aircraft over their volcanoes in Kamchatka. Perhaps we will fly together in the summer of 1993. I'm sure there are members of the military on both sides who will shake their heads in disbelief at the prospect of this exercise of freedom, just as they did at the end of the third week of August last summer. Stay tuned.

David Pieri is a volcanologist and member of the technical staff at NASA's Jet Propulsion Laboratory at Pasadena, California. He divides his volcanological fieldwork between Kamchatka, Hawaii and southern Italy.

World Watch

by Louis D. Friedman

MOSCOW—Events are taking place so rapidly, and profound changes occurring at such a breathtaking pace, that it is impossible to give a current status report on what has become of the Russian space program. In the last week of November 1991, I visited Moscow as part of the international team of scientists working on the *Mars '94/'96* mission. Among the people I conferred with was Academician Yuri Ryzhov—who was introduced to Society members in the July/August 1991 *Planetary Report*. In the one week that I was there, Academician Ryzhov occupied a position in the Supreme Soviet of the USSR, became Boris Yeltsin's science advisor and was appointed ambassador to France.

Although I cannot give a definitive report on a situation that changes daily, I can convey an impression: I saw a determination—at all levels—to carry on activities and to fulfill responsibilities in the space organizations.

Budgets are a major concern because of the severe economic problems, especially inflation, in the USSR. Even if the institutes were to be granted full budgets for their space projects, those budgets would immediately be eaten away by inflation—estimated at well over 200 percent per year. This problem may be insoluble in the short term and may result in severe delays and changes in existing projects.

Boris Yeltsin has reportedly made comments against the space program, but he also has committed to the funding of the Academy of Sciences reconstituted under the Russian government. His new Minister of Science, Higher Education and Technology Policy, Saltikov, told us that Russia would pick up the space program of the USSR and meet its international obligations.

The cost of the *Mars '94/'96* mission is estimated at 500 to 600 million rubles. At today's rate of exchange (in early December), that would be less than $10 million. That is deceptive, since paying for things in the Soviet system was and is very different than in the West. It does, however, emphasize the low cost in Western terms of Soviet space products and suggests that the Western partners (particularly France and Germany, but also other European nations and the United States) can contribute to this project significantly through rather modest increases in their own already committed expenditures.

Germany and France are already major players, with many tens of millions of dollars invested. The US, through its Mars Balloon Relay, has nearly $10 million in this mission. Ideas for such involvement are taking hold in Europe, where, for example, the European Space Agency (ESA) has committed new money to pick up additional responsibility in the *Mars '94/'96* (and other) space projects. ESA is now supplying the computer memory for the Mars orbiter.

The Planetary Society's rover test program is continuing. Russian personnel are still planning to come to the California desert this spring to test their rover. They have decided to give the Society an engineering mock-up of the rover, which we intend to bring to Pasadena shortly.

WASHINGTON, DC—The Space Exploration Initiative (SEI) in NASA has again been reorganized. A new Associate Administrator for Exploration, Michael Griffin, has been appointed. He is drastically reorganizing the Exploration Office's plans and method of operation.

Griffin, formerly with the Department of Defense's Strategic Defense Initiative Organization (SDIO), is emphasizing first the precursor robotic missions necessary for human exploration of the Moon and Mars. He sees a five-phase program, in the following five-year steps.

I Lunar robotic missions 1991-1995
II Mars robotic missions 1996-2000
III Lunar human missions 1996-2000
IV Mars human mission preparations 2001-2005
V Mars human missions 2006 . . .

This is much faster than most observers would anticipate. The key, in Griffin's thinking, is new management approaches in phase I, which show real accomplishments and lower-cost mission developments.

Several lunar missions are being proposed for phase I—for example, lunar orbiters to measure lunar resources, topography and gravity, and lunar landers.

We at The Planetary Society had hoped that a US Mars lander would also be part of the program. We proposed that a US penetrator to investigate subsurface ice and the surface oxidized layer be added to the Russian *Mars '96* mission. The penetrator could have been an adaptation of the Soviet design or one of the designs developed in the military program of the Department of Energy. The total cost was estimated at less than $30 million. Despite a positive review by Griffin, the idea was not put forward for the fiscal year 1993 program.

Although work will focus on the robotic lunar precursors, the Exploration Programs Office at NASA's Johnson Space Center has begun developing the nominal design for the first human Mars mission. The plan for the human mission is three months' flight time from Earth to Mars, 600 days (!) on the surface for exploration, and three months for the flight back. Requirements for this mission are very different from the conventional 8-to-10 month flight times with 30-day stay times that were previously considered.

We'll be following very closely the course of the SEI proposal in Congress' 1993 fiscal year budget considerations.

Louis D. Friedman is the Executive Director of The Planetary Society.

EUROPA: A World o

Image processed by Tammy Becker and Alfred McEwen, USGS, Flagstaff

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What is going on

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# of Superlatives

by Charlene M. Anderson

he smoothest faces yet seen in our solar system. scrossing lineaments have the merest relief; they ks in an eggshell more than canyons and valleys. orightest planetary surfaces known, reflecting 65 ht falling upon it. In comparison, Earth's dark an 12 percent of the sunlight reaching it.
r may conceal a global, subterranean ocean. If so, tential to harbor water-based life.
rlatives and possibilities is Europa, one of the four er, and one of the most intriguing and mysterious spacecraft.
been watching Europa since 1610, when Galileo ope to the heavens and discovered four bright r. With Io, Ganymede and Callisto, the three other pa is easily seen with a rudimentary telescope. But ful telescopes cannot see the details of Europa's s surface it has remained an unresolved speck. Until e jovian system in March 1979, we had little idea ed like.
rajectory took it close by Io (where it revealed active de and Callisto, but Europa's orbit kept the moon ters (450,000 miles) away from *Voyager 1*'s path stem. Nevertheless, many strange dark streaks— owell's imagined martian canals as much as just barely visible to the spacecraft's cameras. We n *Voyager 1*, but we did realize that Europa was d yet seen by humans.
979, *Voyager 2* flew within 206,000 kilometers ropa's surface—and the mystery deepened. Europa range dark lines, which have almost no relief. That tly depressed or raised from their surroundings. y in length from a few kilometers to thousands of e run straight, while others are curved.
t streaks on Europa, called cycloid ridges, that do ut they are still under a few hundred meters in ver 3,000 kilometers (about 1,800 miles, only 15 our own Moon) in diameter, these ridges are barely

rising of all, almost no impact craters have been se are the features by which planetary scientists tell rs there are, the older the surface. *Voyager 2* saw s that resemble impact scars, and this paucity rocess has been erasing the craters.
here? Why is Europa so different from other moons? e in Europa's composition and its position in the s orbiting Jupiter. In the outer solar system, ne reaches, temperatures are so low that water silicate rock on Earth. The icy surfaces of most outer ay craters, cliffs, faults and other features that with on their home planet. At billions of kilometers water is solid enough to maintain these forms.

But on Europa, three quarters of a billion kilometers from the Sun, its surface ice seems to be soft and malleable. It cannot maintain surface features with any appreciable relief. Mountains would simply collapse under their own weight. Impact craters would slowly relax and fade into the soft ice.

The question then becomes, why is Europa's icy surface so soft? Given the densities of water, rock and iron (about 1, 3.5 and 8 grams per cubic centimeter, respectively), a simple calculation shows that Europa, at some 3 grams per cubic centimeter, must have a substantial amount of water. Any water exposed to the cold of space would freeze, as we see on the surface. But beneath that could be a layer where the temperature is high enough for water to exist as a liquid.

On Europa's neighbor, Io, *Voyager 1* discovered erupting volcanoes powered by tides raised by the gravitational pulls of Jupiter and the other Galilean satellites, particularly Europa. Some have speculated that, on Europa, these tidal effects could be providing the energy to maintain a subterranean ocean. That warmer underlayer could keep the surface ice soft enough that it can't maintain topographic relief.

It's also possible that the tidal energy drives water volcanism on Europa, and erupting water could be erasing its relief features and resurfacing the moon.

This image of Europa, created at the United States Geological Survey in Flagstaff, Arizona, combines high-resolution black-and-white images taken by *Voyager 2* with less-detailed color images to produce a high-resolution color picture. With computer processing, the USGS team corrected the differences in brightness among the images so that the brightness of Europa appears uniform across its crescent.

The dark lineaments are the dominant features, but near the terminator (the boundary between the sunlit and dark regions) several of Europa's other distinctive features can be seen.

The bright lines are the cycloid ridges, which scientists believe may be cracks in the icy surface where water oozed up to fill in the gaps. Or they may be compression features formed when sections of ice were pushed together. These bright features are visible only near the terminator, so we don't know if they are found all over the moon.

Near the terminator we can also see shallow depressions that could be almost fully eroded impact craters. Or they could be the scars of the volcanic eruption of water.

Will we ever be able to solve the mysteries of Europa? In 1995, *Galileo* will reach Jupiter and enter a looping orbit among its large moons. With its advanced camera system, this spacecraft should be able to resolve some of these surface features and enable us to figure out what is happening on Europa. Even if its parabolic antenna remains stuck, with data-compression techniques the *Galileo* Imaging Team is looking forward to the return of several thousand new pictures from the spacecraft. Perhaps among them will be a few that will help us understand this world of superlatives.

Charlene M. Anderson is Director of Publications for The Planetary Society.

News & Reviews

by Clark R. Chapman

Perhaps none of our senses ties so directly into our brains as vision. Television's popularity testifies to the power of colored, moving pictures that simulate real life. NASA appreciated long ago the public's demand that it fly cameras on its planetary spacecraft. And recently, thanks to modern computing power and the ingenuity of people like the California Institute of Technology's Eric De Jong, who leads the Solar System Visualization Project, we have been treated to amazing video displays of planets in motion.

De Jong's latest production uses the *Magellan* radar images to simulate a fantastic flight across a gleaming, golden surface of Venus, skimming past Devil's Tower–like volcanoes and soaring over gaping canyons. The October/November 1991 issue of *Air & Space/Smithsonian* features De Jong and the Jet Propulsion Laboratory's Digital Image Animation Laboratory. Author Greg Freiherr tells us just how the magical videos are made—with one exception. Nowhere does he say that most of the oblique views across the venusian landscape are vertically exaggerated by more than 20 to 1.

Geologists frequently exaggerate photographs of gentle topography for their technical research, though rarely by as much as 20 to 1. It helps them see at a glance what is uphill, and whether a linear feature is a ridge or a groove. But it is easy to forget that apparent Rocky Mountain topography could be just a distortion of Nebraska-like rolling plains. If a photo of your house were vertically exaggerated like the Venus pictures, its proportions would more nearly resemble those of the Washington Monument, and it would be unrecognizable as your house.

In none of the television clips or public showings I have seen, nor even in our own *Planetary Report* (which printed a Venus picture in its November/December 1991 issue), has it been noted that these distorted pictures are anything other than colorized, oblique views of Venus as it really is.

There are two other ways that scientists exaggerate planetary images. One is by using time-lapse photography to speed up Jupiter's rotation or the whirling motions of Neptune's great spot. Like slow motion on home videocassette recorders, time-lapse techniques are familiar enough so that I doubt many viewers misunderstand what they are seeing. The second way, color exaggeration, is another matter.

Planetary color differences are often very slight. Subtle but real variations may mark distinct mineral compositions, so scientists "enhance" the colors, compute color ratio images, or even produce those dazzling false-color versions that amaze but baffle most lay people. Not only do scientists unwittingly confuse the public, but they may mislead themselves when they aren't careful about "true" colors.

When *Voyager* first encountered Jupiter 13 years ago, the world was treated to spectacular orange pictures of pizza-like Io. Years later, after many researchers had struggled to understand Io's oranges and reds in terms of temperature-dependent properties of sulfur compounds, Andrew Young managed to convince his colleagues that Io was really a bland greenish yellow. But a tomato-sauce pizza will forever remain our mental image of Io.

Saturn's nearly colorless rings were often portrayed to the world with enhanced spectral colors. And data from one *Voyager* instrument, which made only single scans across the rings—like a radial scratch across a record—were artificially converted in the computer into glowing orange, concentric arcs. Those pretty but largely meaningless pictures were widely reprinted in popular magazines.

I've recently witnessed how *Galileo* scientists responded to media demands for a color picture of Gaspra. While my PhD thesis was on the significant and widely divergent colors of different asteroids, I know that—to the human eye—they all look pretty much like various shades of gray. I was the lone dissenter as the Imaging Team voted to release what the caption later called an "approximately true color" picture of Gaspra. The caption went on to contrast the butterscotch-colored image with the familiar gray rocks of the Moon.

But my caption-writing colleague may have fooled even himself. Look at some of the astronauts' snapshots of lunar landscapes, or just stare at the Moon in the nighttime sky, and consider this fact: Gaspra truly is one of the "reddest" asteroids, but it is *less* red than the Moon!

I think it is time that we ratchet down a few notches from the hype that George Lucas and his Industrial Light and Magic have gotten us used to. Exaggerated color and stereo have appropriate technical purposes. They may even be impressive to the public, if prominently and properly labeled as exaggerations. But if scientists, NASA's public information officials, editors of popular science magazines, and everyone else aren't more careful, we'll all start believing that the solar system really looks the way Eric De Jong is so magnificently portraying it.

Let me close by noting that *Air & Space* regularly carries other articles of interest to Planetary Society members. Accompanying Freiherr's piece is Gerrit Verschuur's article on the asteroid impact hazard. The December 1991/January 1992 issue has a balanced account of the Biosphere 2 project and also an essay about returning to the Moon.

Clark R. Chapman is at the Planetary Science Institute in Tucson, Arizona.

SOCIETY *Notes*

"SISTER WORLDS" AVAILABLE

Since first producing "Mars Watch" in 1988, The Planetary Society has distributed thousands of free educational packets on planetary science to both teachers and the general public. Our current offering is "Sister Worlds: Earth and Venus," an overview of comparative planetology.

"Mars Watch," "Voyager Watch" and "Sister Worlds" have been funded largely through grants from the Norris Foundation. Our thanks to Ken Norris, president of the foundation, for his interest and generous support.

Packet contents include fact sheets, and lesson plans if requested. Also available are accompanying slide and audiocassette tape sets, which may be borrowed for classroom use. So far, the "Sister Worlds" sets have been used by educators throughout the United States and as far afield as Scotland, Iran and Bermuda.

If you would like to receive a copy of "Sister Worlds: Earth and Venus," please write to the Society.

—Louis D. Friedman, Executive Director

CONGRATULATIONS TO SCHOLARSHIP WINNERS

Congratulations to the winners of The Planetary Society's College Fellowships and New Millennium Committee Scholarships for 1991.

College Fellowship Award recipients were David Bearden, Paul Killpack, David Levitt, Sandra Ryan and Mary Urquhart.

New Millennium Award winners were William Buchanan, Eric Choi, Tony Ianello, Douglas Kaupa and Rachel Winston.

They were selected from a group of extremely competent high school and college students planning careers in the planetary sciences.

The 1992 scholarship programs will commence in the spring. Students in their last year of secondary school are eligible for the New Millennium Committee Scholarships. Undergraduate students enrolled in a US or Canadian college or university are eligible for the College Fellowships.

The Mars Institute Student Contest is open to students enrolled in high school or college. For information on these programs, please write to our Scholarship Department.

—Carlos J. Populus, Volunteer Coordinator

IT'S NOW OR NEVER

This is our last reminder that The Planetary Society will be cosponsoring the National Science Teachers Association's annual convention in Boston, March 26 to 29, 1992. Advance registration rates end February 28, so sign up now if you plan to attend.

For details, write to NSTA Convention, c/o The Planetary Society, at our Pasadena headquarters. Or call 1-800-WOW-MARS and request the NSTA package.

— Susan Lendroth, Manager of Events and Communications

INTERNATIONAL SPACE YEAR

International Space Year, 1992, is now under way. For a free directory of special events, write for the ISY Directory, c/o the Society.—*SL*

MARS OBSERVER LAUNCH TOUR

In 1992, the 500th anniversary of Columbus' voyage to the New World, we will celebrate the launch of a spaceship to another world. On September 16, *Mars Observer* is scheduled to lift off from Cape Canaveral on a voyage to Mars, and we would like you to join us in Florida to see it off.

The Planetary Society has organized a special *Mars Observer* Launch Tour for Society members, families and friends.

From September 12 to 19, we have exciting activities in store for you, including visits to Disney's Epcot Center, Spaceport USA at the Kennedy Space Center and the Astronaut Hall of Fame. We will cruise the St. John's River with a naturalist to observe central Florida's flora and fauna, and we'll take a nocturnal tour of the Sanford Zoo.

The highlight will be the *Mars Observer* launch itself, seen from a special viewing area. Experience the launch of a spacecraft to Mars, sped on its journey aboard a powerful *Titan* rocket.

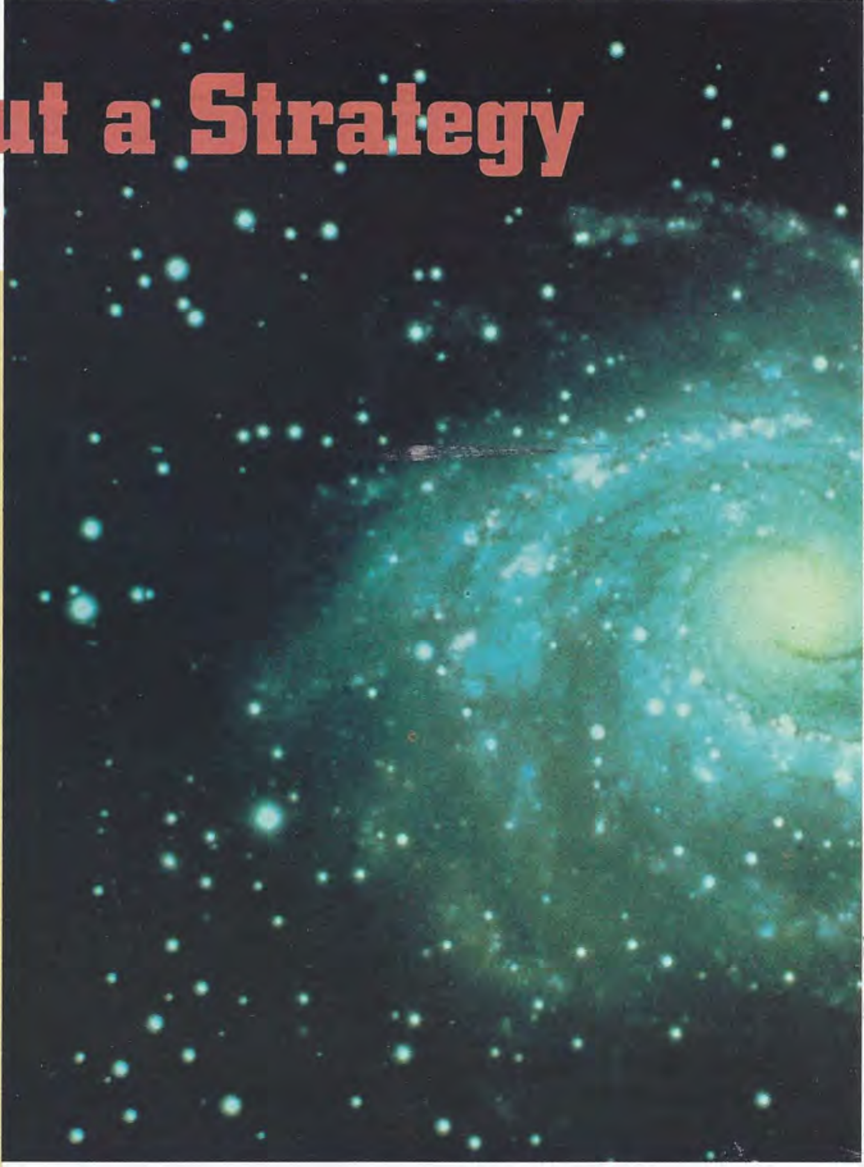
The tour price will include accommodations in fine Cocoa Beach and Orlando hotels, land travel, admission to attractions and most meals. For additional information please write to *Mars Observer* Tour, The Planetary Society, 65 North Catalina Avenue, Pasadena, CA 91106. Or call 1-818-793-5100 and request the information packet (please direct your call to Cindy).

Space is limited, so make your reservations early! *—SL*

Discounts Available for Advance Registration.

Photo: Martin Marietta

Mapping Out a Strategy



A Report From the 1991 SETI Conference

by Thomas R. McDonough

Does extraterrestrial life exist? What experiments can we construct to prove or disprove its existence? There is a small, international coterie of scientists who have devoted their time and thought to answering such questions. A few are even now conducting experiments in an effort called the Search for Extraterrestrial Intelligence (SETI).

SETI has been under way for some three decades now, and while there have been some tantalizing hints, no experiment has yet produced an unambiguous extraterrestrial signal. But the search is just beginning, and only a small fraction of the sky and a small range of frequencies have yet been explored.

We sent The Planetary Society's SETI Coordinator, Thomas R. McDonough, to cover a major meeting of SETI scientists, cosponsored by the Society, and report to the members. Society President Carl Sagan, who had organized the first United States/Soviet conference in 1971, delivered the banquet address.

Every decade, a group of Soviet and American scientists gathers to discuss the past and to plot the future of the Search for Extraterrestrial Intelligence. In August 1991 this meeting was held at the beautiful campus of the University of California at Santa Cruz. It was capably organized by SETI pioneer and Planetary Society Advisor Frank Drake, with the help of the university, the SETI Institute of Mountain View, California, and the Life Sciences Division of NASA headquarters.

I had the pleasure of representing the Society at the meeting, along with Society President Carl Sagan. I'd like to share with members an overview of some of the most important and interesting ideas presented in Santa Cruz.

Planetary Society SETI

Paul Horowitz of Harvard University, creator of META, The Planetary Society's SETI project and the most powerful program operating anywhere on Earth, surveyed its five-year history. (META is an acronym for Megachannel ExtraTerrestrial Assay.) He has picked up several mysterious signals over the years, signals very narrow in frequency—the kind we suspect another civilization would use as a beacon proclaiming its existence. Most likely, these signals are from our own civilization. However, none of them have repeated, and until they

There are hundreds of billions of stars in a typical galaxy, and many billions—perhaps hundreds of billions—of galaxies in the universe. Many scientists argue that in such a vast arena life should have arisen on innumerable worlds. Perhaps this spiral galaxy, NGC 2992, harbors millions of technical civilizations more advanced than ours. While the more distant the source the weaker the signal, the most advanced civilizations might be in the most distant galaxies. For this reason it pays to look both at stars in our Milky Way galaxy (foreground objects in this photo) and at more distant galaxies like our own.

Photo: David Malin, courtesy of the Hansen Planetarium

repeat we don't know for sure whether they're from our own radio noise or someone else's beacon.

There are two nearly identical METAs: META I at Harvard and META II at the Institute of Radioastronomy in Argentina, also supported by The Planetary Society. Samuel Gulkis of the Jet Propulsion Laboratory (JPL) had just been to the Argentine site, and he described the work being done there by Raul Colomb, Eduardo Hurrel, Juan Carlos Olalde and Guillermo Lemarchand.

This group of scientists is operating the world's only permanent Southern Hemisphere SETI system. They have detected a number of strong signals, but, as with META I, it appears that these are the products of our own civilization.

Philip Morrison, the SETI pioneer from the Massachusetts Institute of Technology and a Planetary Society Advisor, observed that the turning on of META II was a historic occasion, because now we are observing the southern half of the universe, where little SETI work has been done.

Horowitz discussed The Planetary Society's grand plans for the next step beyond META: BETA, the *Billion*-channel ExtraTerrestrial Assay. In its preliminary form, BETA will have 100 million channels, over 10 times the 8.4 million channels of the META receivers. The additional channels will allow us to prospect beyond the highly concentrated bits of the microwave spectrum we have focused on thus far. Eventually, the system could be expanded to 6 billion channels. The Society is now raising funds for this exciting project.

NASA's Program

NASA has come up with a two-pronged approach to SETI, shared by JPL and the Ames Research Center. Whereas JPL will search the entire sky for a radio beacon, Ames will observe particular stars similar to our Sun. The NASA program is scheduled to begin on October 12, 1992, in honor of the Columbus quincentennial, and it will eventually cover much of the atmosphere's microwave window.

JPL scientists summarized the all-sky survey. Michael Klein related that tests made using a prototype have already detected faint signals from the old *Pioneer 10* spacecraft out beyond Pluto. This marks the first time we've detected intelligence beyond the planetary part of our solar system—but it is of our own creation.

Edward Olsen of JPL reported that any SETI program is going to have to deal with the blaring radio noise being generated here on Earth. His group is devising techniques to detect and avoid such interference.

To look at specific Sun-like stars, the Ames researchers will take a trailer full of equipment to different telescope sites in North America, Australia and elsewhere. According to Peter Backus, they'll start out at the Arecibo Observatory in Puerto Rico, using its giant 300-meter (1,000-foot) dish antenna. The telescope will be aimed at one star at a time, and will listen to it for a long period in order to detect faint signals.

Soviet SETI

Valery Altunin of the Soviet Institute of Astronomy spoke about using the large antennas of the Soviet deep-space antenna network to search for extraterrestrial radio signals. These antennas, similar to the ones NASA uses to communicate with interplanetary spacecraft, are as large as 70 meters (about 200 feet) in diameter. They are located near the Crimean Sea, in the Soviet Far East and elsewhere in the Soviet Union. He hopes that the United States will provide some of NASA's SETI technology, such as the signal-processing equipment used in the Ames project.

Gregorii Beskin of the Special Astrophysical Observatory of the USSR talked about looking for pulses of visible light from other civilizations. He is continuing the work of the late astronomer V.F. Schvartsman in a project called MANIA. His team is searching for pulses a civilization might transmit by laser, anything from 1 pulse every 1,000 seconds to 10 million per second. Using their giant 6-meter (20-foot) optical telescope, they have found 20 objects so far, but these seem to be natural, though uncommon, astronomical objects.

Nikolay Kardashev of the Institute of Astronomy is well known in the SETI community for his imaginative ideas about the powers of really advanced civilizations able to harness the energy of stars and even of galaxies.

He emphasized the importance not only of continuing SETI but also of searching for vast structures that might be erected in zero gravity by advanced civilizations. They

Pebbles on the Massachusetts Shore

by Phylis Morrison

How would extraterrestrials encode a message to send across space to demonstrate their existence? One simple way would be to transmit a binary code, such as Morse code or computer code. But other codes are possible, and here's an example of a binary message transmitted through time.

Photo: Phylis Morrison

Down the restaurant table the computer expert asked, "Would you believe a message that appeared only in binary could be the result of intelligence?" (He knew nothing of SETI; his field was complex molecules.)

I *do* know of a binary message that convinced me of the intelligence of its remote originator.

We start with an unusual exhibit in the Boston Museum of Fine Arts. In a case in the Asian wing I found seven rounded river pebbles, arranged in a crescent, increasing in size along the row. They were not carved, not the work of hands in any way that could be seen. They seemed too simple in a setting devoted to high art and culture. The first hint of why they were there was their origin in Harappa, an ancient ruined town along the Indus River. The museum had sent an archaeological expedition there; these were part of the wonders they had found.

The label explained that the pebbles were weights, found among other materials in the quarter of the town where bead-makers had lived and worked. Each pebble weighed twice what the smaller pebble next to it weighed, a true binary sequence, capable of producing every unit from 1 to 2^7 on their beadstuff pan balances. I was fascinated by the pebbles, and by the thought that had made them, for they were not made by hands; they were shaped only by the river. They were purely informational, artifacts of the mind.

Next time I went to the beach, I took along an equal-arm balance I had made for myself and searched out my own set of pebble-weights. I started by finding two small pebbles that balanced each other well; the next weight in my set was the pebble that was equal to those two weights together. Then 2, 4, 8, 16 . . . my set of weights grew. I had grasped a binary message convincingly sent by intelligent beings, distant in time by 4,000 years.

The binary coding here was not merely arithmetical, with 2 as the smallest value of a base for positional notation. It was deeply physical, the direct consequence of the symmetry of the equal-arm balance and the additivity of weights. But its meaning was certain; the informational choices we had both made linked me to those clever artisans of the past.

Phylis Morrison hangs out with Philip Morrison waiting for a SETI message.

could make huge habitats in space, even enclosing stars, as Freeman Dyson of the Institute for Advanced Study in Princeton, New Jersey, has proposed. As Kardashev pointed out, there are "no limits for construction of solid bodies in space."

He described a ground-based 70-meter radio telescope near Samarkand, which is to begin operating in 1993. He hopes that it will be used 30 percent of the time for SETI.

Although the future of the Soviet space program is uncertain, scientists are anticipating the launch of a satellite called Radioastron several years from now. This is an orbiting 10-meter-diameter radio telescope that could be used part of the time for SETI. They're already looking ahead to the next step beyond Radioastron, a 25-meter radio telescope dish in space.

Some Conference Highlights

Stuart Bowyer and Daniel Werthimer of the University of California at Berkeley discussed Project SERENDIP, which piggybacks on existing radio telescopes. By tapping into the antenna with a SETI receiver while astronomers do conventional radio work, SERENDIP is able to search for artificial signals without interrupting astronomical research.

They are building a new, much more powerful model, SERENDIP III, to operate at Arecibo. With 4 million channels, this will make SERENDIP even more important to SETI.

Jim Cordes of Cornell University was inspired by an idea that Thomas Gold had in 1976, based on the existence in space of natural masers—interstellar gas clouds that amplify radio signals. Gold had wondered whether an advanced civilization might take advantage of such an object, perhaps placing a transmitter on one side of the cloud and making it a giant amplifier. Cordes elaborated on this idea and showed that such a maser could be used to make a signal detectable from 10,000 times farther away than otherwise possible.

He also talked about a phenomenon of pulsar signals known as scintillation—the twinkling of cosmic radio signals. Just as Earth's atmosphere causes starlight to appear brighter, then dimmer, radio signals fade and strengthen as they pass through interstellar blobs of ionized gas.

Cordes pointed out that sometimes these signals are *strengthened* by twinkling, so that it may in fact enhance our chances of detecting very faint signals from other civilizations. I suggested that this might explain some of the signals that have not repeated. Perhaps there's a civilization whose faint signal is amplified from time to time by interstellar twinkling to the point where we can detect it.

Until recently, SETI workers have largely ignored certain parts of the electromagnetic spectrum, especially frequencies higher than microwave. Most scientists have concentrated on radio because the technology to detect radio waves is so well developed, and because the universe is especially quiet in this part of the spectrum. But several scientists at the meeting believe that we should study higher frequencies as well, such as millimeter-wavelength radio, infrared and visible light.

Paul Steffes of the Georgia Institute of Technology discussed looking for extraterrestrial signals at millimeter wavelengths—shorter than microwave but longer than infrared. The technology to observe these very short waves is now available, and it appears to be a logical step after the microwave spectrum has been thoroughly explored. He emphasized that we should concentrate on microwaves first because satellite transmissions are making these frequencies increasingly noisy.

Albert Betz of the University of California at Berkeley talked about searching for artificial infrared laser signals, perhaps similar to the huge Antares laser that was built at the Los Alamos laboratory. For an instant, one such laser can produce a million million watts. Using a 10-meter (30-foot) mirror, a 1-million-watt laser could reach across 160 light-years to an identical system. Betz has begun a search for laser signals from stars near our Sun.

He also mentioned that under certain conditions a carbon dioxide atmosphere may amplify infrared signals just as a laser could. He referred to a speculation that another civilization might use a planet with a carbon dioxide atmosphere like Venus as a giant laser to amplify signals.

Soviet astrophysicist Andrei Linde, a visiting scientist at Stanford University, gave a mind-stretching talk about how the universe may be far larger than we think it is. His mathematical models showed that the universe could have many regions that are virtually independent. In each of these "bubbles," the laws of physics could be different. If he's right, then what we normally think of as the universe is just a little bubble in a far vaster whole.

New Planets?

Several observatories in Canada and the United States are using precise astronomical measurements to search for planets around other stars. Frank Drake said that the Shuttle Infrared Telescope Facility, scheduled to fly about the year 2000—if it is funded in the near future—may be able to image extrasolar planets a bit larger than Jupiter.

Just weeks before the Santa Cruz meeting, a planet was detected where no one had expected one to be—orbiting a pulsar. For decades, scientists have reported detecting planets around other stars, but every case has been disputed. This pulsar planet may be the first one that everyone can agree is real.

But a pulsar is formed in the aftermath of a supernova explosion, the most violent event observed in nature. According to prevailing thought, no planet should have survived it.

Some scientists think that this planet did somehow weather the explosion. But Douglas Lin and Stanford Woosley of the University of California at Santa Cruz presented a different theory. They believe that the planet was made afterward, from the explosion's debris. Their explanation proposes that some of the expelled gas fell back, forming Saturn-like rings around the pulsar, and eventually a planet condensed out.

They have nicknamed the planet "Phoenix" because it arose from the ashes, in contrast to what, in their competitors' models, they call "Zombies"—dead planets surviving a supernova. If the Phoenix theory is correct, planet formation may be even easier than we thought.

The Future

Freeman Dyson summarized the conference, spicing it with his own provocative ideas. For example, he thinks that if we decide to reply to a signal from another civilization, it's best to respond not with just a single voice but with many, because humanity has a multitude of voices. We should not let any one voice dominate our response.

Dyson believes that a really advanced civilization will not be confined to a single planet. Creatures disperse, and new species form. "One intelligent species becomes a million in a short time," he said. He thinks that we should not confine our searches just to stars, but should look at the whole sky as we do in META and in NASA's all-sky survey.

If a being could live on a billion-ton comet, Dyson observed, 100 million watts of starlight would be available wherever the comet happened to be in the galaxy. Comets may even provide stepping-stones to interstellar space: Beings could move outward from their sun by using these iceballs for water, fuel and the chemical building blocks of food. Over centuries, they could transfer to increasingly distant comets.

Scientists should look at the interstellar "cirrus clouds" seen by infrared light, Dyson said. These wisps are clouds of gas and dust, and he thinks this is where life might spread once it was ready to move off its home planet.

Dyson also believes that an alien civilization would probably erect "field stations" at interesting places. For example, any civilization blessed with enough technology and curiosity would investigate black holes, globular star clusters and active galactic nuclei. "Wherever you have exciting stuff going on, you will have scientific crazies looking on," he said. Searches directed at such places might pick up signals from these interstellar scientific expeditions.

What will be presented at the next conference in this series, in the year 2001? The Planetary Society's BETA project will have (we hope!) been scanning the skies for several years. NASA's program will have been operating for nine years. Scientists from around the world will have joined the search in earnest. With perseverance, ingenuity and a lot of luck, in 2001 we will be discussing the first conclusive proof of the existence of a civilization beyond our Earth.

Tom McDonough is the author of Space: The Next 25 Years *(Wiley) and the novel* The Missing Matter *(Bantam).*

Questions & Answers

Will it be possible to steer the Mars Balloon, or will it be stuck studying the areas where it happens to drift?
—Kirby Milner, Kansas City, Missouri

The first balloon on Mars, a part of the Soviet-French *Mars '96* mission, will have no steering capability. It will follow the winds over Mars' surface at night (while dragging the SNAKE guide-rope along the ground), and will drift with the daytime winds at about 4 kilometers (2 to 3 miles) altitude.

The Planetary Society has done research showing the feasibility of using a "smart balloon" that can control its path by choosing the best altitudes at which to fly. This would allow it to find the desired winds to get from one selected area on Mars to another. The Society has developed a concept in which a series of these balloons would be used in an international program to carry out a planetwide Mars sample-collection mission. We call this the "Elephant Graveyard" mission.

Here a dual-envelope balloon known as a *canniballoon* would be used. It has one compartment filled with a lifting gas (helium or hydrogen) and a second filled with martian air. Its total floating mass is less than 100 kilograms (220 pounds), so it can be launched from Earth with a low-cost rocket like a *Delta*.

When heated by infrared radiation from the Sun, the air inside the balloon provides controllable amounts of lift. An on-board computer operates a valve, or curtain, in the balloon's side (much like a common hot-air sport balloon). This lift control allows continuous adjustment of the balloon's altitude during the day. At night it rests on the SNAKE.

By finding the altitudes at which the winds are blowing in the directions it wants to go, a canniballoon can guide itself to a series of scientifically interesting locations. Upon arrival, it would descend, document the area by television imagery, land on its SNAKE, anchor at a particularly attractive location, and then collect the desired surface or subsurface samples.

If the site is a particularly interesting location for a later landing (human or robotic), it would be marked by a beacon left behind by the balloon. As soon as the balloon completes its task of collecting 5 to 10 documented samples, it will again use the variable martian winds to propel itself to the "Elephant Graveyard," a preselected area where all of the balloons terminate their lives. In this smooth, level area (perhaps 100 kilometers, or 60 miles in diameter), all of the balloons will deposit their sample cairns. Each cairn will contain a beacon to aid in sample retrieval.

When enough balloon missions have been successfully accomplished (over perhaps 6 to 10 years), a rover/sample-return mission would then be dispatched to Mars to pick up the documented samples collected from across the face of the entire planet.

—TOM HEINSHEIMER, *Aerospace Consultant*

In the November/December 1991 issue of The Planetary Report, *Bruce Hallock asked why the satellites of planets in our solar system do not have any satellites of their own. In his answer to this question, Gustaf Arrhenius discussed the possibility that magnetic fields played an important role in the situation. Here James Pollack answers this question in a somewhat different fashion.*

In a fundamental sense, all the planets of this solar system are "satellites" of the Sun; that is, they are in orbit around it. We think that they formed from the solar nebula, gases and small, solid particles within a flattened disk of material that surrounded the early Sun. Mercury, Venus, Earth, Mars and Pluto formed almost exclusively from the solid particles, while the gas giants—Jupiter, Saturn, Uranus and Neptune—formed from both the gas and solids of the solar nebula.

The gas giants may have grown initially as solid bodies by collecting, through gentle collisions, smaller nearby solid bodies. But these early gas giants may have become massive enough—perhaps 10 to 30 times as massive as Earth—to effectively concentrate a lot of the gases of the solar nebula around themselves by gravitational forces.

Unlike the solid planets of the solar system, each giant planet has a rich collection of satellites. Most of these probably formed within flattened disks that surrounded the early giant planets, since their orbits lie close to the equatorial plane of the parent planet.

These satellite-forming disks may have come into existence, directly or indirectly, from gases and small particles that flowed from the solar nebula toward the early giant planets. Because this gas was rotating and it spun faster and faster as it flowed inward, it may have rotated fast enough at some distance above a giant planet's surface for its centrifugal force (the same force that throws people outward on a merry-go-round) to balance the planet's gravitational force, and thereby form a transient, flattened disk.

No satellite, including those of the giant planets, is massive enough to have been able to capture gas from its surroundings, and thus could not have formed satellites of its own from surrounding disks of gas and dust.

Satellites such as our own Moon, Pluto's moon Charon and perhaps the small moons of Mars may have formed in a different way: from the collision of big, solid bodies with even bigger solid bodies—planets. Not every such collision produces a moon. The colliding body may need to have a mass not much smaller than that of the planet it is striking (to distort the figure of the planet and thereby make it easier to put fragments into orbit around it). It may also need to have a low approach velocity (otherwise most of the ejecta from the collision may escape from the planet's gravitational influence).

The satellites of the solar system may have had a hard time making satellites of

their own in this way and an even harder time keeping them. Because the satellites are in orbit about their parent planet, stray solid bodies tend to hit them at a high velocity. Even if satellites of satellites were produced, they probably would not survive for long because there is a large number of stray solid bodies in the solar system—asteroids and comets—that are big enough to totally fragment small satellites upon collision. Similar-sized stray bodies produce craters when they hit bigger bodies, such as large satellites and solid planets.
—JAMES B. POLLACK, *NASA Ames Research Center*

FACTINOS

New radar observations of Mercury indicate that the planet's polar regions, which get little or no sunlight, appear to be covered with deposits of water ice. Scientists said the discovery was surprising and could have important implications for future exploration of the Moon, where conditions are similar. If the Moon has undetected polar ice, it could be a more attractive place for human outposts.

Last August, astronomers from the California Institute of Technology and the Jet Propulsion Laboratory produced the first radar images (see photo) of an entire hemisphere of the planet. The images showed an especially bright region at the north pole that, the scientists said, had all the characteristics of ice reflecting the signals. Duane Muhleman, a professor of planetary science at Caltech, acknowledged that the interpretations were preliminary and that other explanations could be made for the bright polar area. "But we regard these alternatives as farfetched," he said.
—from John Noble Wilford in *The New York Times*

❖

The ring system of Uranus has revealed a wealth of new structures, reports Mark R. Showalter of Stanford University. By applying some advanced processing techniques to about 50 *Voyager* images, he has been able to detect ring structures 30 to 200 times fainter than those visible in the early *Voyager* images.

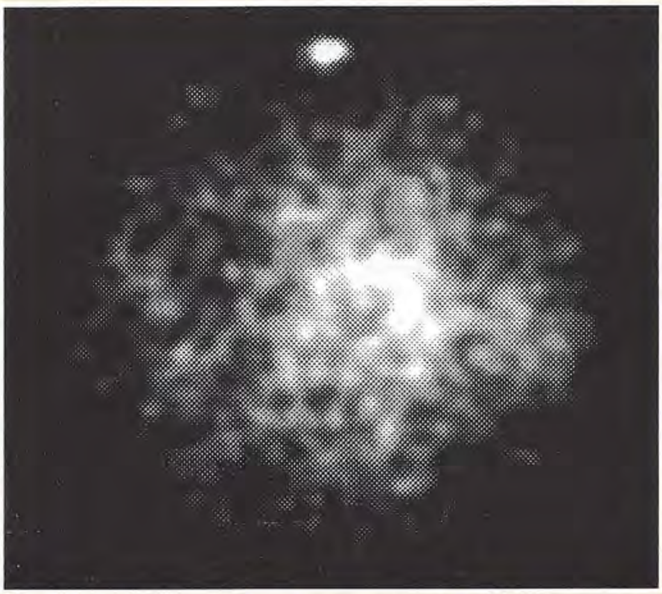
Uranus' ring system has long been known to comprise nine narrow rings, but Showalter has discovered at least two more rings, which lie among the nine but are only a few percent as bright.

But the most surprising result of Showalter's work has been the discovery of clumps and arcs within the uranian Lambda Ring (see photo). The Lambda Ring was discovered during the 1986 *Voyager* encounter, since it is too faint to be detected from Earth's surface.
—from NASA Ames Research Center

❖

An unusual comet has been identified by Uwe Fink of the University of Arizona. His spectral studies indicate that comet Yanaka belongs to a new class of comets—one whose members may have originally orbited a Milky Way star other than the Sun.

In January 1989 (when Yanaka was only 34 million miles from Earth), Fink collected three light emission spectra from the comet. Though the spectra indicate that Yanaka contains normal amounts of ammonia, the data reveal no evidence of cyanogen or carbon. Even at much greater distances from the Sun, the vast majority of comets—including Halley—show detectable levels of both compounds, Fink observes. "No other comet in our spectral library has shown this behavior," he says.
—from R. Cowen in *Science News*



In this new radar image of Mercury, variations in surface reflectivity revealed broad topographic features and an apparent ice cap at the north pole. The bright area near the equator shows a large basin where temperatures can climb to 425 degrees Celsius (800 degrees Fahrenheit).

The white parts of this image represent areas of high reflectivity, but only the spot at the north pole has the reflective characteristics of deposits of frozen water. The scientists said they assumed that similar ice deposits would be found at Mercury's south pole. *Photo: California Institute of Technology*

Upon closer inspection of Uranus' Lambda Ring, Mark Showalter found that it breaks up into five major arcs of roughly equal length, sharing a common orbit. Each arc is then composed of still finer structure. Showalter found one Voyager image that, after careful processing, clearly shows an isolated clump within one arc. This clump (at the left of the image) is about 1,200 kilometers (750 miles) long.
Photo: NASA Ames Research Center

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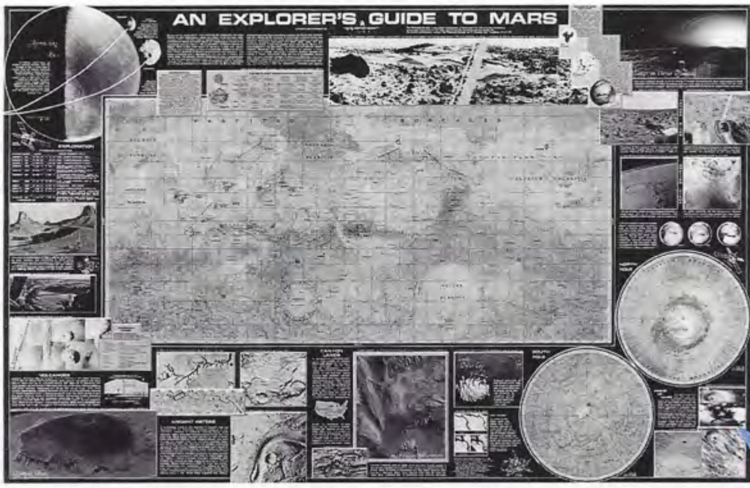

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Approx. 35 min. videocassette. 2 lb.
VHS (US) **420**, BETA (US) **421**, PAL (Europe) **422** **$25.00**

An Explorer's Guide to Mars
For enthusiasts and students of the Red Planet. This 40" x 26" full-color poster surrounds a central map of Mars' surface with photos, paintings, polar projections and images taken by *Viking* spacecraft. Text presents brief discussions of the planet's canyons, winds, volcanoes and more.
1 lb. **505** **$5.00**

Exploring the Universe 1992 Calendar
Celebrate your interest in astronomy every day of the year with our lavishly illustrated space calendar, produced by the creators of *Astronomy* magazine in cooperation with The Planetary Society. Each month features a striking full-color photograph or painting, and dates noted include many births and anniversaries important to the history of space science. Columns of text cover subjects ranging from Supernova 1987A to Isaac Newton's conception of universal gravitation, while an additional feature, "The Planets This Month," offers viewing information. 2 lb. **520** **$8.00**

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A Planetary Miscellany

Note: Although we have fewer items listed here this month, most of the merchandise that has appeared in previous issues of* The Planetary Report *is still available. For a complete list of items available, please call 1-818-793-1675.

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These four 20" x 16" color reproductions include a Mars landscape taken by the *Viking* Orbiter, Jupiter's southern hemisphere, a full-view photograph of Earth and the sunlit crescent of Uranus. Order separately, or purchase all four at a special discount. 2 lb.

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By Alan Harris and Paul Weissman. Takes young readers on a journey through time and space to the distant reaches of our solar system. For ages 10-14. 79 pages.
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Artist Greg Mort has a strong interest in space science. He is a member of NASA's Fine Arts Program, and "Earth and Moon" is a part of NASA's space art collection. His work has appeared on the cover of Sky and Telescope *and in Isaac Asimov's* Library of the Universe.

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